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US ARMY MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

REPORT NO. 617

CHANGES IN Cs^{137} RETENTION AND ROUTES OF ELIMINATION AS EFFECTED BY EXTERNAL FACTORS

by

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Captain G. M. Lodde, MSC
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7 January 1965

UNITED STATES ARMY
MEDICAL RESEARCH AND DEVELOPMENT COMMAND

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Division of Biophysics
US ARMY MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

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ABSTRACT

CHANGES IN Cs^{137} RETENTION AND ROUTES OF ELIMINATION AS EFFECTED BY EXTERNAL FACTORS

OBJECT

To study changes in Cesium-137 retention and routes of elimination in the rat as effected by external factors.

RESULTS AND CONCLUSION

Partial and whole body X-irradiation increased the biological half-time of Cesium-137, while cold with the associated increased food consumption and fluid exchange decreased the biological half-time. Analysis of fecal and urine outputs showed that increased diuresis does not invariably facilitate Cesium-137 excretion.

RECOMMENDATIONS

1. Study changes in Cesium-137 retention and routes of elimination by irradiated rats exposed to extreme external temperatures.

2. Investigate the significance of physical performance as related to the retention and excretion of Cesium-137.

essentially excluded, small amounts of scatter radiation were received in the shielded areas (Fig. 1).

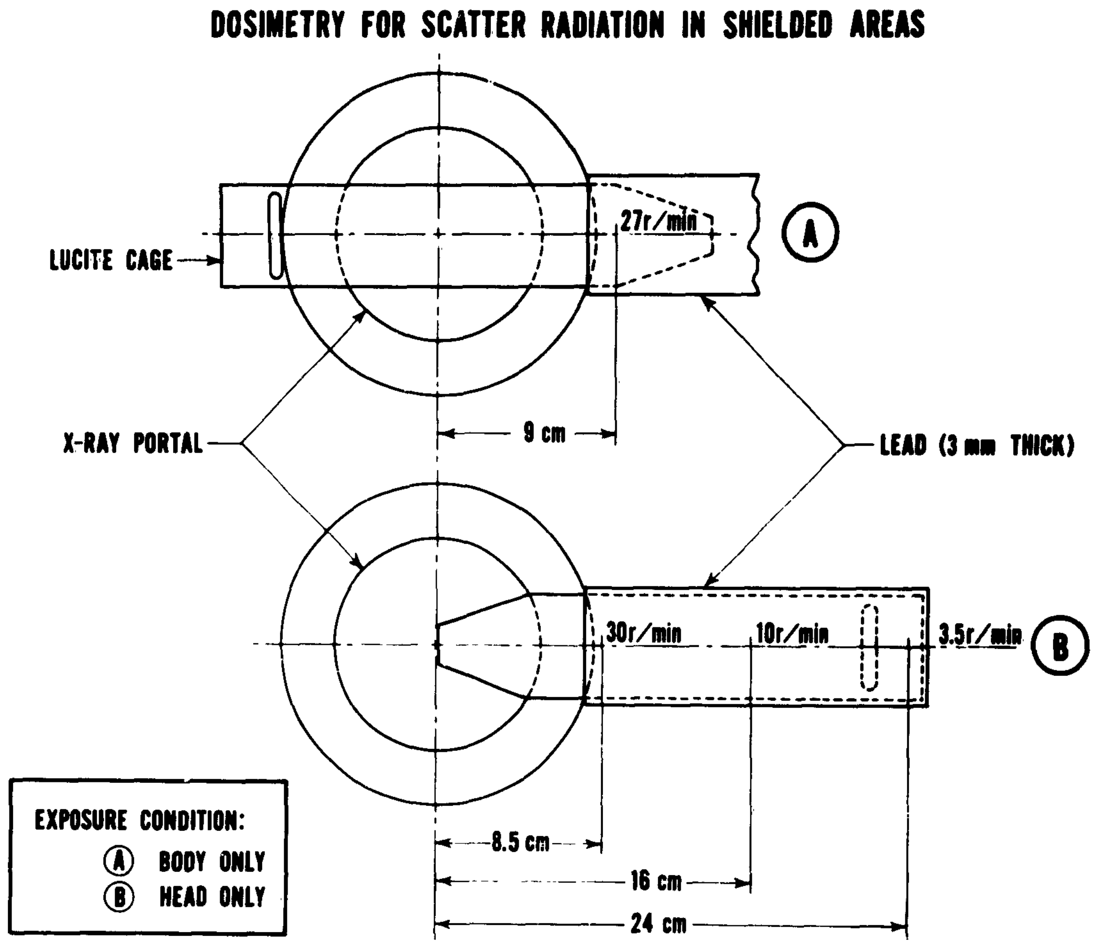

Fig. 1. Dosimetry for scatter radiation in shielded areas.

The X rays were delivered by a General Electric Maxitron Unit operated at 250 kvp, 30 ma, 4.75 mm Be inherent filtration, 1 mm Al + 0.5 mm Cu added filtration, HVL 1.1 mm Cu. The dose measured in air with a 250 r Victoreen Ionization Chamber was 673 r/minute at a target midline distance of 21 cm.

Ten minutes after X-ray exposure, each rat was injected intraperitoneally (ip) with 1 ml of double distilled water containing 0.25

microcuries of Cs^{137}. Animals subjected to heat and cold were injected with an equal amount of the Cs^{137} solution following a 7-day exposure period. Aliquots of the injected solutions were set aside for use as standards.

Animals were radioassayed individually 30 minutes following injection and at 24-hour intervals thereafter. Counts were determined by a prototype whole body detector developed for Army field work. The detector utilized a NaI crystal 4 inches in diameter and 5 inches thick, coupled to a Du Mont K-1209 photomultiplier tube 5 inches in diameter. The crystal-photomultiplier combination was connected with an Auto-Gamma single-channel spectrometer.

The spectrometer was calibrated with a 2.55×10^5 dpm Cs^{137} standard. To insure optimum counting conditions, a wide window setting (550 - 730 Kev) which encompassed the entire photopeak of Cs^{137} was maintained throughout the investigation. To obtain the most efficient distribution in total counting time between sample and background, and to minimize the error introduced by the background, adjustments in counting time were made for each sample (10). That is, as the sample count rate decreased, the background counting time was increased.

The mean whole body count measured 30 minutes following ip injection of Cs^{137} served as the 100 per cent whole body count. Fractional biological retention levels of the isotope were calculated by the following expression (11):

$$\text{Biological } R_t = \frac{\left(\dfrac{\text{animal count rate}}{\text{standard count rate}}\right)_n}{\left(\dfrac{\text{animal count rate}}{\text{standard count rate}}\right)_o}$$

The subscripts n and o refer to time after isotope administration and R_t is the biological retention at any given time. This expression corrects for decay and minor day-to-day fluctuations in background counts.

Urine and feces were collected and counted separately (aliquots of 3 ml and 2 g, respectively) at 24-hour intervals. Excreta were counted with a well type scintillation detector, using a 2-inch NaI crystal, and the results were expressed as a mean per cent of the initial whole body count. Cs^{137} standards counted with the two detecting systems (whole body and deep well) provided an efficiency factor used in correlating excreta counts with whole body counts.

III. RESULTS

Data relevant to changes in Cs^{137} retention and Cs^{137} elimination through urine and feces are given in Figures 2-4. Mean values of food and water consumption are given in Tables 1 and 2. Only the animals

TABLE 1

Mean Food Intake

Days Post Inj.	Controls g	550 r WB g	1200 r WB g	1200 r HO g	1200 r BO g	Cold g
1	12.5(13)	7.6(5)	9.4(10)	4.0(5)	6.6(5)	20.8(6)
2	19.8(13)	9.8(5)	7.2(10)	12.0(5)	7.4(5)	26.5(6)
3	11.8(13)	9.6(5)	1.4(10)	10.8(5)	2.6(5)	21.7(6)
4	13.7(13)	10.2(5)	1.0(6)	10.6(5)	1.7(4)	24.0(6)
5	11.8(13)	10.2(5)	0.25(4)	11.2(5)	5.0(4)	34.5(6)
6	16.1(13)	12.6(5)	0.7(3)	11.4(5)	5.0(4)	22.7(6)
7	15.5(13)	12.6(5)	1.0(3)	11.4(5)	4.7(4)	28.0(6)
8	16.7(13)	12.4(5)	0.5(2)	11.0(5)	6.5(4)	26.5(6)
9	16.2(13)	16.6(5)		14.6(5)	11.2(4)	26.8(6)
10	11.8(13)	14.2(5)		14.6(5)	10.0(4)	28.5(6)

Number in parenthesis indicates the number of animals.

TABLE 2

Mean Water Intake

Days Post Inj.	Controls ml	550 r WB ml	1200 r WB ml	1200 r HO ml	1200 r BO ml	Cold ml
1	48.2(13)	59.8(5)	59.3(10)	79.2(5)	77.8(4)	35.7(6)
2	39.1(13)	50.4(5)	43.0(10)	44.8(5)	63.8(4)	34.7(6)
3	36.4(13)	24.8(5)	10.7(10)	45.6(5)	15.6(4)	38.0(6)
4	39.5(13)	30.8(5)	12.0(6)	42.8(5)	11.3(4)	31.8(6)
5	39.5(13)	32.2(5)	5.5(4)	36.2(5)	20.0(4)	34.5(6)
6	39.9(13)	37.4(5)	25.0(3)	31.6(5)	55.5(4)	42.2(6)
7	38.7(13)	36.2(5)	3.0(3)	22.0(5)	60.0(4)	50.1(6)
8	38.4(13)	35.4(5)	5.0(2)	23.2(5)	54.3(4)	43.3(6)
9	41.7(13)	38.4(5)	1.5(2)	30.8(5)	53.5(4)	54.4(6)
10	43.1(13)	34.6(5)		29.4(5)	49.3(4)	70.0(6)

Number in parenthesis indicates the number of animals.

subjected to 1200 r WB irradiation, all of which died between days 3 and 9, failed to survive the post injection observation period. Data concerning animals exposed to heat are not included, since the time course for radiocesium elimination by this group was essentially the same as that shown for the control group. The temperature differential of 5°C between these two groups may have been too small to bring about a significant difference in Cs^{137} retention.

Mean percentages of whole body Cs^{137} retention plotted as a function of time for each group of animals are shown in Figure 2.

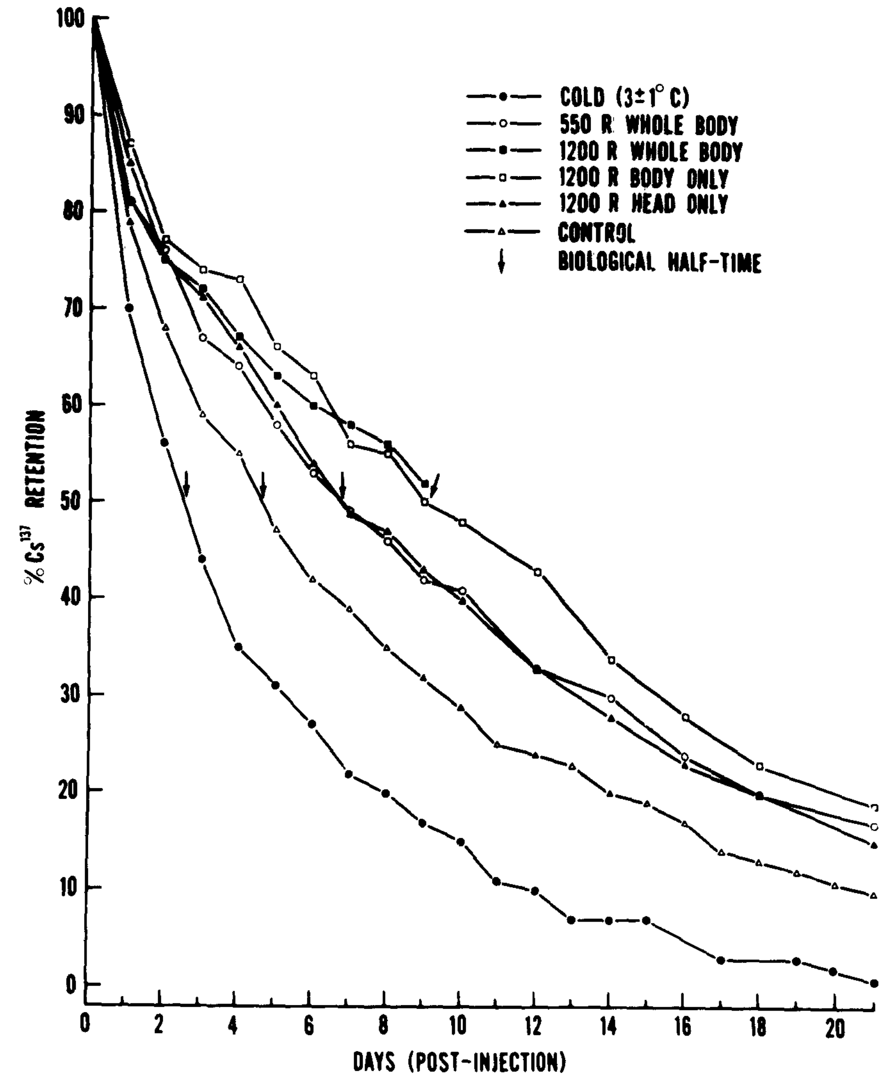

Fig. 2. The influence of environmental factors upon Cs^{137} retention in rats as a function of time.

Under control conditions the injected dose of Cs^{137} was reduced by 50 per cent in about 4.5 days. At a like time interval animals administered similar doses but kept in a cold environment had excreted nearly 65 per cent of the radiocesium. An inhibitory effect on radiocesium elimination, however, prevailed in animals receiving either partial or whole body X-irradiation. As a result, the T_B of Cs^{137} in animals exposed to 550 r WB, 1200 r HO, and 1200 r BO was extended to 6.9 days, 7.1 days and 9.0 days, respectively.

The retention data in Figure 1 were subjected to a statistical analysis based on the T_B obtained for each rat (excluding those in the 1200 r WB group, all of which died before the T_B was reached). The difference in biological half-times among groups was significant at $P < .001$ (Kruskal - Wallis $H = 21.8$, 4 degrees of freedom). U-tests indicated that when any two groups were compared the results were significant at the one tailed .05 level or better, except that there was no significant difference between the 550 r WB and 1200 r HO groups.

Cumulative differences in mean values of urine volume and urinary Cs^{137} excretion (per cent of injected dose) as compared with control measurements are shown in Figure 3 (page 7). On the first two days following isotope injection the water exchange was highest in X-irradiated animals, but Cs^{137} elimination through urine was less than of other groups. For the same period cold treated animals, with a urinary output greater than controls but less than X-irradiated animals, had the highest urinary Cs^{137} release.

Figure 4 (page 7) shows that irradiated animals had the lowest fecal output and a concomitant lower fecal Cs^{137} release. Figure 4 also shows that cold treated animals had the highest fecal output (especially during the first three days subsequent to isotope injection) and excreted more Cs^{137} through fecal material than any other group.

A statistical assessment of the excretory data was made to determine the influence of environmental factors on the relative roles urine and fecal material played in the elimination of Cs^{137}. Ratios of fecal Cs^{137} to urinary Cs^{137} were calculated separately for each rat for the period between Cs^{137} injection and the T_B. Results of the analysis showed that a significant difference existed among groups (Kruskal - Wallis $H = 10.67$, $P < .05$). Further analysis by means of U-tests revealed that the significant difference was obtained because the control and cold groups excreted a higher proportion of cesium through fecal material, and the irradiated animals excreted the

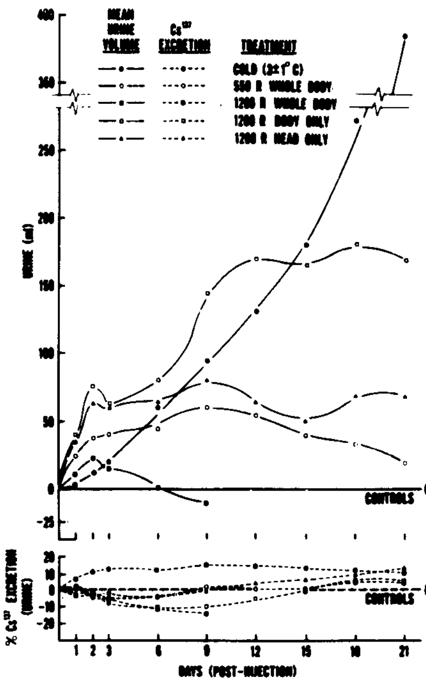

Fig. 3. Cumulative differences (mean) between urine volume and urinary Cs^{137} excretion of treated animals from that of controls.

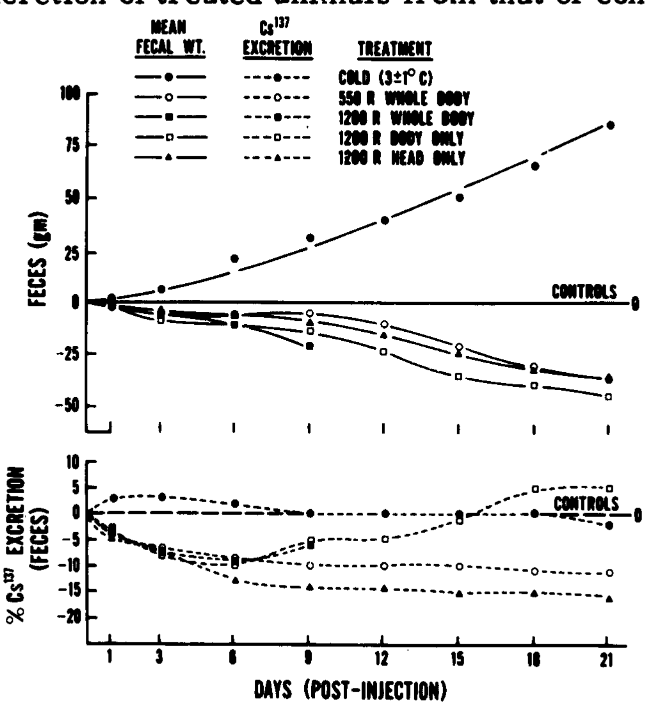

Fig. 4. Cumulative differences (mean) between fecal volume and fecal Cs^{137} excretion of treated animals from that of controls.

highest proportion through the urine. No significant difference, however, existed between the control and the cold group. Since the amount of Cs^{137} excreted in the urine per day by the irradiated animals was less than that of any other group (Fig. 3), the relatively greater role of urine apparently occurred because less cesium was excreted via the fecal route, not because of an increase in urine volume.

IV. DISCUSSION

The results of the present study are in good agreement with those reported by other workers regarding urine as the major pathway of Cs^{137} elimination (7-9) and the polyuria-polydipsia effect following X-irradiation (12). Inasmuch as urine is of prime importance in Cs^{137} elimination, changes in urinary volume would be expected to effect the T_B of Cs^{137}. In the case of cold treated animals, the present results support this speculation; radiation, however, extended the T_B.

The latter result differs from that reported by Kereiakes *et al.* (5) where irradiated animals retained less Cs^{137} than corresponding non-irradiated control animals. A possible explanation lies in a procedural difference between the studies; whereas the Kereiakes rats were starved, ours were fed *ad lib.*

A comparison of data from the two studies showed that three days following isotope injection, Cs^{137} retention was similar in the irradiated animals but differed in the control animals; Kereiakes *et al.* reported a retention of 81 per cent, while our control rats retained only 58 per cent. If the difference in retention is related to food consumption, it is likely that the potassium content in the diet (.72 per cent) was a contributing factor (13, 14). Furthermore, the fecal material resulting from food assimilation, provides an additional means for removing displaced Cs^{137}.

This line of reasoning may also explain the similarity in Cs^{137} retention between the Kereiakes starved (72 per cent) and our non-starved animals (67 per cent), which received comparable X-irradiation exposures of 600 r and 550 r, respectively. Because irradiation produced anorexia, the fed animals were more like the starved.

The apparent relationship between food mass passing through the body and radiocesium excretion is borne out further by the fact that rats subjected to a cold environment ate and defecated more (1.5 - 3x) than any other group of animals and, also, demonstrated the shortest Cs^{137} biological half-time. Furchner and Richmond (14) using mice reported similar changes in biological half-time.

The present study shows that even though Cs^{137} is primarily eliminated by way of the urine, an increase in urine flow does not necessarily facilitate the release of Cs^{137}. This phenomenon is apparently dependent on the cause of diuresis. For instance, the X-irradiation induced polydipsia-polyuria condition occurred concurrently with the time of highest Cs^{137} body content (first 2 days following injection) but failed to augment Cs^{137} elimination. The cold exposed animals, on the other hand, had an increased urine flow which was accompanied by a more rapid release of Cs^{137}.

V. CONCLUSION

This study shows that exposure to a cold environment increases Cs^{137} excretion, while X-irradiation decreases Cs^{137} excretion. Since both cold and irradiation produce a diuretic state, it is apparent that diuresis does not invariably facilitate Cs^{137} excretion. Evidence is supplied which indicates that high food intake and fecal output result in increased radiocesium elimination.

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Investigations were made to determine the roles that cold and X-irradiation played upon the T_B of Cesium-137 in rats. Partial and whole-body X-irradiation increased the biological half-time of Cesium-137 while cold with the associated increased food consumption and fluid exchange decreased the biological half-time. Analysis of fecal and urine outputs showed that increased diuresis does not invariably facilitate Cesium-137 excretion. The possible roles of food ingestion and fecal outputs were discussed.

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